



Dear Bahamian Reef Survey Volunteers

In 2007, we had many significant achievements. First, you contributed to one of the longest running coral reef ecology research projects in the world. You also helped me welcome the Living Jewels, the island of San Salvador's environmental organization, to the project and forged what I believe will be a long-lasting working relationship with the people of San Salvador.

In the summer of 2007, we collected initial baseline data within future restoration study plots on San Salvador's reefs. I am sure you recall me speaking of the continued observed decline of coral reefs around the planet and on San Salvador. In an attempt to halt this decline, the project is going to devote a portion of future studies to identifying the effectiveness and feasibility of coral reef restoration techniques, especially those designed for remote communities. We are also going to conduct studies to determine the effectiveness of San Salvador's proposed marine park.

Last summer we also had our first "teen team". Fourteen young, enthusiastic volunteers pitched in and collected some great data. Notably, through the use of GPS technology, we began to track the location and growth rates of endangered species that have begun to re-appear around the island. In addition, the teen team helped me with some initial coral transplant activities.

Finally, in November, 2007, we welcomed three teachers who participated in Earthwatch's "Live from the Field" program. These intrepid educators brought the wonders of San Salvador's reefs to their students back home via webcasting. Seven more "Live from the Field" teachers came in February 2008, with many more to follow in the coming years.

All of the project's achievements and successes would not have been possible without your time, energy, good cheer, and contributions. On behalf of myself, my co-principal investigators, and the project's staff scientists – I want to say THANK YOU! You are all warmly welcomed back to San Salvador, but if you cannot make it back, at the very least, please do stay in touch!!

Sincerely,

John Rollino

Earthwatch Institute Annual Field Report

Project title: Bahamian Reef Survey

Completed by: John Rollino

Period covered by this report: 1/1/07 to 12/31/07

Reporting on research objectives

Objective 1: *Conduct one of the most comprehensive patch reef monitoring projects in the world / continue the long-term study of the decline of coral reefs on San Salvador, Bahamas*

To date, the project is one of the longest-running coral reef research projects in the world. Research has been collected since 1992. The project's data set represents one of the most comprehensive and continuous data collection efforts on coral patch reefs in the Atlantic. Moreover, few scientific studies have focused on patch reefs, which are shallow, easily accessible reefs close to the shoreline. Their proximity to anthropogenic resources results in their being disproportionately affected by pollution, runoff, fishing, and tourism-related activities. The PI currently has research activities associated with this project planned for the next decade.

Objective 2: *Determine long-term trends (seasonal, annual, and decadal) of floral and faunal assemblages that live on coral reefs. Correlate these trends to variation in species populations, change in physical and chemical parameters, and/or local and regional recovery or mortality of corals.*

Since 1992 the project has tracked recruitment (seasonal and annual), mortality and survivability of coral species, and has covered the before and after periods for four major hurricanes and three bleaching events. There has been an observed decline in the percent coverage of hard coral and an increase in the percent coverage of algae. Figure 1 illustrates the percent coverage of coral and algae on the project's study sites over the past decade. Also, further analysis of the data indicates there has been a decrease in the number of valuable branching and reef building corals; however, there has been a slight increase in the number of stress tolerant corals.

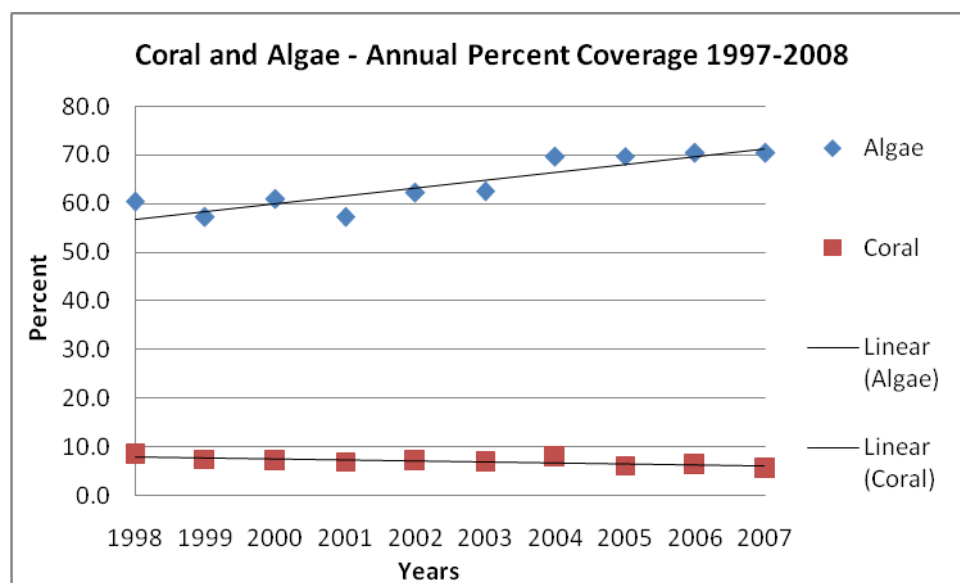


Figure 1. Annual percentage coverage of coral and algae in San Salvador for the period of 1997-2008.

The functional ecology groups of algal populations have begun to shift. Fleshy algae, a key competitor of corals for sunlight, have begun to dominate. Overall, rugosity (reef structure three-dimensionality), has shown a slight decline and fish populations still remain low. Although, there has been a reappearance of endangered species that were absent from the study site's reefs for many years.

Studies documenting the long term trends will continue on the project, and new studies designed to quantify emerging trends will be initiated when appropriate.

Objective 3: *Correlate physical and/or chemical changes in the shallow water, near-shore environment(s) to the overall health of coral reefs on San Salvador.*

Three times a year, water quality samples are collected for analysis in near shore environments (depth 1-2 meters) around the island. Samples are also collected approximately 0.8 kilometres offshore. Water quality samples are analyzed for two suites of data: Physical Parameters (i.e. pH, salinity, visibility) and Chemical Parameters (i.e. levels of ammonia, boron, calcium, copper, iodine, DKH/alkalinity, magnesium, nitrate, nitrite, dissolved oxygen, phosphate, silicate and strontium). Analysis of the results shows that water quality is remarkably homogenous (similar across the whole area) and is not believed to be a significant factor in observed trends to date. Water quality samples will continue to be collected in the future, and there are plans to involve local school groups to perform observations during time periods when Earthwatch teams are not on the island.

Objective 4: *Introduce new studies to document and follow observed emerging trends in coral reef ecology.*

Several additional studies have been introduced as a result of observations made on the project: They are the following:

Endangered species surveys

In the spring of 2006, the US government placed two species of hard coral (elkhorn, *Acropora palmata*, and staghorn, *Acropora cervicornis*) on the Endangered Species List. These species were once prevalent on many of San Salvador's reefs; however, the population suffered severe mortality in the late 20th century. In late 2006, individual *Acropora* species were observed once again on the patch reefs around San Salvador. In order to better document and understand the establishment (and possible recovery) of the *Acropora* population, a study was initiated in 2007. The Principal Investigator had the volunteers swim over the reefs and search for *Acropora* species. Once sighted, the species locations were marked by GPS (Global Positioning System) and the surface area of individual colonies was measured. This exercise will be repeated in 2008 and subsequent years to quantify the recruitment of any new individuals, the mortality/survivability of species, and species growth rates. Observations are also noted with respect to changes in fish population in areas where *Acropora* are or will be established.

Coral Reef Restoration

In order to increase the percentage of hard coral cover and increase fish habitat and rugosity (reef structure three-dimensionality), a restoration strategy has been developed where volunteers randomly swim over the reefs looking for coral heads that became detached, in order to re-attach them to the reef using thin wire or epoxy (note that volunteers wore gloves during this procedure). Replaced coral heads were photographed, measured, and marked with GPS. Volunteers also constructed casts of coral heads out of wire and concrete which will be placed on the reef in established study plots to determine fish usage of the additional reef structure. Future studies will determine if the increase in rugosity will increase fish abundance, lower algal abundance, and ultimately increase hard coral recruitment. Also, coral recruitment on the newly placed hard substrates will be quantified.

Caribbean long-spined sea urchin and algae studies

The Caribbean long-spined sea urchin, *Diadema antillarum*, is a major consumer of algae on coral reefs. In 1984, there was an almost complete die-off of these organisms in the region. From 1996 to 2001, the PI observed no *D. antillarum* on the project's study site reefs. In 2002-2003, isolated adult individuals of *D. antillarum* were infrequently observed; in 2004 one adult individual of *D. antillarum* was observed during each expedition and several more *D. antillarum* were observed in 2004-2006.

In 2007, 8mx8m study plots were established on the project's study sites. Within these plots, the PI and volunteers searched for the presence of *D. antillarum*. When observed, the location, number of individuals and age category (adult/juvenile) were recorded. *D. antillarum* show high site fidelity and each future expedition will re-examine the study plots to determine any change in *D. antillarum* populations. There are also plans to involve the local community in surveying additional reefs of San Salvador for *D. antillarum*.

A comprehensive algae study has been initiated in conjunction with the *Diadema* study. In the same study plots and also randomly on the reef, the composition of algae populations are identified by their functional groups: Macro algae (calcareous and fleshy), encrusting and turf. In the future, the change in the composition of algal functional groups will be analysed against the change in *D. antillarum* populations. Since the inception of the study, *D. antillarum* have been virtually absent from the reefs; however, anecdotal reports from researchers in the 1970s and early 80s indicate that *D. antillarum* populations were very high on San Salvador's reefs in the past. Also, coral coverage was much higher and algae coverage was much lower.

Project development

1. If you have removed or modified your original objectives please explain why below.

Review of data collected over the project's 15-year history indicates the following: coral coverage is declining; algae (marine plants that compete with coral) is increasing; rugosity (the reef's three-dimensionality) is declining and fish populations remain low. In an effort to increase coral coverage, the project initiated baseline studies for coral reef restoration activities.

With the continued observed decline of coral reefs, predicted effects of climate change, and a continuing population rise that will undoubtedly place additional pressure on coral reefs, the PI has decided to increase the amount of time spent on reef restoration studies. Previous monitoring studies will still continue; however, several minor exercises associated with the project (e.g. studies of corals living in tide pools) will be scaled back. The rationale for the shift in effort is simple - there is now a clear and pressing need to determine restoration efforts that halt the decline of reefs before an ecosystem collapse.

It is the hope of the PI to develop an effective, low-cost coral reef restoration method that can be implemented by remote, low-income communities (See objective 4 in the previous section).

2. Please list any new objectives below.

See Objective 4 in the previous section.

In 2007, additional studies were added to the project. These studies included: reef restoration studies; additional flora and fauna studies; and tracking the re-occurrence(s) of endangered species that had died off from San Salvador's reefs in the 1980s and late 1990s, and their effect on reef ecology.

3. What logistical or scientific challenges have you encountered in the past season and how will you address these during the next field season?

Challenges encountered include working on a remote island and the need to collect additional data to determine marine park effectiveness. The project will now utilize local help, including teens, to serve as a “force multiplier” to increase the amount of data collection.

Non-technical summary of results

1. Give an account of the data collected and results (inputs and data) for the period covered by this report, mentioning any emerging trends.

In 2007, volunteers on the Bahamian Reef Survey conducted the following studies:

- Bleaching studies along the project’s eight permanent 10m transects;
- Coral mapping (mapping every hard coral along the each of the eight permanent 10m transects);
- Cover-type analysis (identification of the percent composition of hard coral, soft coral, sponge, algae, sand, rock, and other);
- Water quality analyses;
- Rugosity measurements;
- Reef height and depth measurements;
- *Diadema* and algae studies;
- Baseline coral reef restoration studies (establishing study plots, floral and faunal studies with plots);
- Coral transplants;
- Endangered species surveys;
- Beach profiles.

Water quality samples collected and analyzed in February, July, and November of 2007 were generally consistent with past results; although, for the summer expedition, salinity and pH readings were slightly lower than past summers. This is likely due to torrential rain that occurred on San Salvador for the entire week prior to the expedition. The increased input of freshwater diluted the shallow bays around San Salvador.

Bleaching studies for the February, July, and November expeditions revealed that only a limited number of corals exhibited signs of bleaching. Most of the corals were less than 5 percent bleached. These findings are consistent with other “non-bleaching” events.

Percent cover-type studies were collected on February, July, and November expeditions. Percentages of hard coral recorded (Summer 2007) on the three main study sites: Lindsay’s Reef, Rocky Point, and Rice Bay were 8.1%, 6.4% and 2.2% respectively. Table 1 depicts percentage of hard coral coverage and total algae coverage on our reefs since 1994. As you can see in the table, the percentage of hard coral has decreased while the percent of algae has increased.

Coral mapping activities conducted in summer 2007 determined that there were 242 corals on Lindsay’s Reef transects, 259 corals on Rocky Point transects and only 85 corals on Rice Bay Transects. On Lindsay’s Reef, Transect C (95 corals) was mapped for the first time in the Summer of 2007. The total number of hard corals is similar to that recorded in 2006.

After monitoring the corals for 14 years, in 2007 new research protocols were initiated. These protocols are designed to do the following:

- Find new, low-cost methods to restore coral reefs
- Track the effects on reef ecology resulting from the establishment of a marine park around portions of San Salvador.
- Track the effects of the natural re-establishment of endangered species on reef ecology

These protocols included the formal placement of test squares (quadrats) on Lindsay's Reef (total N=4), Rocky Point (N=4) and French Bay (N=2). Within these test squares the total coral cover-types were measured, a refined algal study was initiated, population counts of *Diadema* sp. were performed and damaged elkhorn coral (*Acropora palmate*), were transplanted.

Are the Caribbean long-spined sea urchin, *Diadema antillarum*, populations returning? *D. antillarum*, is a major consumer of algae on coral reefs. In 2005 the PI, John Rollino, examined an 800m² area for *D. antillarum* on Lindsay's Reef and observed just three individuals. In the summer of 2007 the Earthwatch team examined four 8mx8m study plots, a total of 256m², and recorded 18 individuals.

In the future, the change in the composition of algal functional groups will be observed with the change in *D. antillarum* populations. Since the inception of the study, *D. antillarum* have been virtuously absent from the reefs; however, anecdotal reports from researchers in the 1970s and early 80s indicate that *D. antillarum* populations were very high on San Salvador's reefs. Also, coral coverage was much higher and algae coverage was much lower.

Table 1. Percentage of coral and algal cover on the reefs around San Salvador 1994-2007.

Year	Percent Coral Coverage	Percent Coral Algae
1994	8.0	60.7
1995	7.8	75.0
1996	7.0	60.9
1997	6.2	66.6
1998	8.5	60.3
1999	7.5	57.2
2000	7.1	61.0
2001	6.9	57.2
2002	7.2	62.2
2003	6.9	62.5
2004	8.0	69.7
2005	6.1	69.8
2006	6.3	70.4
2007	5.7	69.6

Also, in the summer 2007 expedition, individuals of the endangered species of the *Acropora* genus were located on using GPS and measured to determine annual growth and recruitment.

There are several clear trends that have emerged from the data.

- 1) Hard coral coverage is declining, especially valuable branching and reef-building corals. There has been a slight increase in the number of stress tolerant corals.
- 2) Algae populations are increasing. Macro algae (calcareous and fleshy) that compete for sunlight with corals are increasing in number.

- 3) Fish populations remain low. What is interesting is that not only are predatory fish (e.g. groupers, snappers, etc.) populations low, so too are herbivorous fish populations, despite the abundance of algae.
- 4) The continued decline of hard coral coverage has begun to show in reef rugosity readings.

2. How do these data contribute to achieving **conservation impacts?** (e.g. actions based on results, management plans, site protection)

Due to the findings of scientists who have performed research on San Salvador, the local environmental group on the island prepared an application to have portions of San Salvador's marine habitats included in a marine park. The proposal is now under review by the Bahamian Parliament.

This project can assist in marine conservation in two significant ways:

- 1) The project's study sites are located in and outside of the proposed marine park boundaries. Review of future data can assist in determining the effectiveness of the marine park once it has been established.
- 2) The project has engaged in reef restoration activities and utilizes the assistance of the local population. Involving the local community in the research and repair of the reefs will further enhance their sense of ownership of the island's natural resources. Moreover, it will show the population first hand the benefits of conservation.

3. What is/ are the **significance/ benefits** of your research at the following levels?

- Local (to the area of the research site)

San Salvador is a small, lightly-populated island located some 325 miles east-southeast of Miami. The island's isolation and low levels of anthropogenic disturbance make it an ideal place for a long-term coral reef research project. Also, the effectiveness of future reef restoration activities can be measured due the limited anthropogenic influence.

- National / Regional

The project's study sites are located both inside and outside of a proposed marine park. Future data collected by the project can assist in determining the effectiveness of the marine park. Also, reef restoration efforts conducted by the project can determine effectiveness of restoration and potential effectiveness of the synergy between regulations (i.e. marine park enforcement) and restoration activities.

- International

One of the ultimate results of the research could be the creation of a coral reef restoration technique designed for implementation on small remote islands. Many coral reefs around the world are located within the political boundaries of small island states. The creation and/or refinement of restoration techniques, coupled with the enforcement of a marine park may serve as a model strategy for other countries - especially nations with limited financial resources available for the promotion and encouragement of reef restoration and conservation activities.

Communication of results

Printed: peer reviewed scientific publications; books / book sections; reports, management plans or policies; fact sheets, brochures, leaflets, pamphlets, posters, academic dissertations, annual reports, proceedings of conferences or workshops; letters; newsletters.

- McGrath, Smith, Rollino. Sept 2007. A Decade-Long Evaluation of Three Patch Reefs Off San Salvador. *Bahamas Journal of Science*. Vol 2, Issue 2.

Digital: database; internet - websites, email group/ blog/forum; CD Rom, e-newsletter

The following are blogs related to the "Live from the Field" program. The articles mention the teachers experience, the project and PI, and Earthwatch:

<http://www.wickedlocal.com/roslindale/news/x1993301991>

<http://shusd.schoolwires.com/1573201114111825857/blank/browse.asp?A=383&BMDRN=2000&BCOB=0&C=56213>

http://www.livescience.com/imageoftheday/siod_061215.html

<http://xit.manatee.k12.fl.us/?blog=SMitchell>

<http://www.ibabuzz.com/chalktalk/2008/02/12/remote-teacher/>

Other websites that mentioned the project include:

<http://volunteering.boomerscape.com/bs-listingsp3.cfm/listing/18420/hostx/boomerscape>

<http://news.surf wax.com/hobbies/files/Snorkeling.html>

<http://www.tyco.com/livesite/Page/Tyco/Our+Commitment/Community/Community+Focus/Revitalizing+Science+for+Students+and+Teachers/> (article on PI John Rollino's research activities with Earthwatch. Tyco has approximately 200,000 employees worldwide)

Mass media: broadcast production; film; TV, radio, print (newspaper/ magazine coverage); Press releases; press conference; interview, article creation; press trip

- May Issue (2008) Article on the project in Conde Naste Traveler
- *Teacher named top history instructor*, Oakland Tribune, Feb 18, 2008 (article on an Earthwatch TEACHER Fellow who participated in Live From the Field)
- John Rollino was also interviewed by National Geographic Kids magazine and the St. Petersburg Times; however, a search of the internet cannot locate the articles.

Other (specify):

School District of Manatee County, Florida. *The Manatee Educator*, December, 2007. 20pgs. Monthly Newsletter (article regarding the project and Sarah Mitchell, 11/07 Live from the Field Teacher)

Educational Opportunities

1. Does your project directly or indirectly involve the following groups in your research topic?
 - Local communities - YES
 - Students - YES
 - Early career scientists - YES
 - Other groups - YES
2. How does your research help these groups better understand and act towards the conservation of a sustainable environment?

All groups benefit from the project by seeing first hand the results of the research. Moreover, the length of the project clearly illustrates the decline of coral reefs and need to preserve and restore them.

Local Community and Students

1. Members of the Living Jewels, the island's environmental organization, have assisted in the project. Inclusion of the islands environmental group provides first hand knowledge of the coral reef ecosystem.
2. Students of the local high school will participate as Earthwatch Volunteers in the project's Teen Team this summer.
3. Removal of Invasive Species – An invasive shrub/tree species, Australian Pine, has become established on San Salvador. In the future, on days when weather conditions prohibit in-water research activities, Bahamian Reef Survey Research teams will assist in the removal of this species. It should be noted that the Principal Investigator, John Rollino, and project staff scientist, Ms. Lisa Montana are both Certified Arborists. The assistance of removing these invasive species will further strengthen Earthwatch's bond and involvement with the local population.

Early Career Scientists

Some members of the project staff are teachers with less than five years' work experience. Other members of the staff are currently pursuing their graduate degrees.

Other Groups

Live from the Field teams and other educators make regular appearances on the project.

3. Has your project contributed to the completion of Masters' or PhD theses or degrees, or other educational research findings?

Some members of the project research staff are pursuing graduate degrees and are designing portions of their academic research to occur on San Salvador. These studies are designed with the thought that they will compliment the project's research.

Other

Is there anything else you would like to tell us about? (E.g. unexpected outcomes, quotes, etc)

This study illustrates the value of Earthwatch to the global community. Earthwatch has provided a vehicle for the PI to collect a long, baseline of data, which will prove invaluable in future reef restoration efforts and other marine science studies. As mentioned previously,

the Bahamian Reef Survey is one of the longest running coral reef research projects in the world.

Acknowledgements

I would like to acknowledge the outstanding efforts of Heather Pruiksmá and Alison Whelan of Earthwatch. Their efforts have been first rate!